Theme Session on the Spatial Dimension of Ecosystem Structure and Dynamics (L)

ICES CM 2005/L:01

Vital population rates across multiple spatial scales: A geostatistical analysis

Elizabeth T. Methratta, and Jason Link

Population and community level processes change across multiple spatial scales. Understanding these patterns and the factors that drive them are essential for the development of spatial approaches in fisheries management. Determining appropriately-resolved spatial scales is further complicated in temperate marine ecosystems by the generally high mobility and low site fidelity of temperate species compared to those in tropical reef systems. Spatial variability in per capita vital population rates (e.g., consumption, mortality, growth, survival) can directly affect the population level dynamics of managed species. Benthic habitat characteristics also change across spatial dimensions and may contribute to the differential spatial variability in vital rates. We used a set of bioenergetic equations to compute the daily per capita rate of consumption and mortality for individual groundfish species. These estimates used data from the US National Marine Fisheries Service Northeast Fisheries Science Center bottom trawls and food habits data sets. A geographic information system (GIS) was created to map these vital rates at multiple spatial scales. The spatial variability and spatial independence of vital rates were then explored using geostatistical techniques. Multivariate statistical approaches were also used to examine how habitat characteristics may be influencing spatial patterns in vital rates. Our results demonstrate the challenge of evaluating key population processes at the most appropriate spatial scales. Yet the demonstrated ability to integrate individual, population, and habitat information across multiple spatial scales should enhance our ability to manage our living marine resources.

Keywords: spatial statistics, consumption, mortality, groundfish, fisheries management, essential fish habitat, NW Atlantic.

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ICES CM 2005/L:02

An overview of EMAX: The northeast U.S. continental shelf ecological network

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Notable changes have occurred in the northeast U.S. continental shelf LME. To evaluate the response of this ecosystem to numerous human-induced perturbations, as well as to explore possible future scenarios, the Northeast Fisheries Science Center instituted the Energy Modeling and Analysis eXercise (EMAX). The primary goal of EMAX was to establish an ecological network model (i.e., a more nuanced energy budget) of the entire Northeast U.S. food web. The EMAX work focused on 4 subregions of the ecosystem from contemporary times (1996–2000), had 34 network "nodes" or biomass state variables across a broad range of the biological hierarchy, was highly interdisciplinary, and incorporated a wide range of key rate processes. The emphasis of EMAX was to explore the particular role of small pelagic fishes in the ecosystem. Various model configurations were constructed and pseudo-dynamic scenarios were evaluated to explore how potential changes to the small pelagic fishes can affect the rest of the food web. Our results show that small pelagic fishes are clearly keystone species in the ecosystem. There are some differences across the four EMAX regions reflective of the local biology, but major patterns of network properties are similar over space. The contemporary results of EMAX are quite distinct to prior energy budgets from the same ecosystem. Finally, EMAX will continue to play a critical role for the further development of EAF as: a catalogue of information and data; identifying major fluxes among biotic components of the ecosystem; a basis for further analytical models; a way to evaluate biomass tradeoffs; and a backdrop for a suite of other relevant, management and research questions.

Keywords: network analysis, energy budget, food web, trophodynamics, ecosystem approaches to fisheries management.

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ICES CM 2005/L:03

Spatial and temporal overlap and trophic interactions between Atlantic saithe (*Pollachius virens*) and Norwegian spring spawning herring (*Clupea harengus*) on herring spawning grounds

Aril Slotte, Arne Runde, Georg Skaret, Bjørn Erik Axelsen, Anders Fernö, Arne Johannessen, Leif Nøttestad, and Jan Tore Øvredal

Atlantic saithe (*Pollachius virens*) and Norwegian spring-spawning herring (*Clupea harengus*) represent two of the most abundant and ecologically important fish species in the Northeast Atlantic. The two species co-occur in the Vesterålen/Lofoten area during the wintering of herring, but the temporal and spatial overlap between species in different scales as well as their trophic interactions is otherwise largely unknown. Saithe is a potentially important predator on herring. In the present study we found the commercial catches of saithe off western Norway to be closely related to the migration of herring into the coastal spawning grounds, indicating that saithe follow the high concentrations of migrating herring. Acoustic surveys within a defined study area demonstrated that the species overlapped spatially and temporarily. Degree of overlap varied both diurnally and with the maturity status of the herring (pre-spawning, spawning or spent). Concurrent catches of saithe and herring from trawling and gillnets supported an overlap also on the meso-scale. Observations on more fine-scaled behaviour obtained from an underwater rig with high-sensity cameras positioned in high-density areas of herring demonstrated that the distribution and behaviour of herring and saithe was closely linked to the diel light cycle and spawning of herring. When looking at the actual outcome of the interactions between the species on a kind of temporally, integrated spatial microscale, it was observed that stomachs of large saithe (>50 cm) on average contained 2–3 herring, while the stomachs of smaller saithe were filled with herring eggs. This suggests a considerable predation pressure by saithe on different life stages of herring.

Keywords: saithe-herring interaction, underwater camera, acoustics, commercial catch data.

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ICES CM 2005/L:04

Factors affecting sardine and anchovy egg distribution in the Bay of Biscay

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Sardine and anchovy eggs distribution in the Bay of Biscay was investigated in single spring cruises from 1999 to 2003 and during three cruises in spring 2004. The stations were located every 3 nautical miles covering the shelf and shelf-break, from –1.20ºW to –4.25º W and from 43.37ºN to 46.6º N. From 1999 to 2003 together with eggs, surface salinity, temperature and mesozooplankton (PVA) abundance and size structure data were collected. During the three cruises in 2004 we collected vertically resolved hydrographical data (CTD), microplankton (Flowcam) and mesozooplankton (PVA) abundance and size structure data. The sardine and anchovy egg distribution was analysed as a function of the hydrography, microplankton and mesozooplankton distribution using quotient analysis and multivariate statistical methods. As expected temperature plays a main role determining spawning. However, in spatial terms there is a discrimination between the sardine and anchovy spawning areas that can be related to hydrograpical structures (river plumes, shelfbreak front).

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ICES CM 2005/L:05

A natural "model" environment (MARE MINIMUM) for studies of ecosystem dynamics with emphasis on herring spawning dynamics

Arne Johannessen, Leif Nøttestad, Bjørn Erik Axelsen, Anders Fernö, Rune Vabø, and Jan Tore Øvredal

As marine research is expensive and resource demanding, it is crucial to identify systems and localities that are restricted in space, yet large enough for important processes to be realistically reconstructed. Along the coastline of Norway, several fjords inhabit local fish stocks. Lindåspollene in Western Norway has earlier been subject to academic studies by the University of Bergen and Institute of Marine Research. In 1961 ICES recommended studies on small, self-contained, easily accessible herring stocks to improve knowledge of herring biology, and a multidisciplinary project was initiated on herring and its environment. Herring spawning biology and early life history, as well as migration and growth of the adult herring were studied during the 1970–1980s.

Recently, a growing interest of marine science is devoted to “model environments” where well-defined, natural process-oriented experiments can be conducted. In the pre-spawning season of herring in 2005, the spatial dynamics and school dynamics of herring were studied with echosounder and multibeam sonar supported by light sensitive UW-video-camera, CTD and hydrophones. Gill nets collected data on age and size structure and maturity as well as trophic interactions. Observations suggested that the spatial location of herring spawning had not changed in the last 30 years. Studies at meso- and micro-scale levels were found appropriate to reveal the response of pre-spawning herring to the surrounding environment (various environmental factors and predators), as well as the dynamics of individuals in a school. The results encourage future scientific studies of processes to be integrated into holistic ecosystem studies. There is also a large potential in linking academic research with education, exhibitions and public outreach activities.

Keywords: model ecosystem, herring spawning dynamics, predators, underwater video, sonar, echosounder, education, outreach.

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ICES CM 2005/L:06

SMAST Decision Support System: a spatially quantitative tool for ecosystem fisheries management

Tu H. Truong, Yue Jiao, Farhad Azadivar, and Brian J. Rothschild

This paper presents a Decision Support System (DSS) leading towards an ecosystem fisheries management approach. The concept in fisheries management has evolved from single-species interest to explicit consideration of ecosystem, multispecies interactions. The DSS considers multiple stocks and fisheries simultaneously in balancing catch among targeting and protected fish abundances, taking gear effect on habitat into account. We focused on spatial fisheries management given spatial variability in fish distribution, fishing activities, catch-per-unit-effort, bycatch and habitat. An effective spatial management model requires a high resolution monitoring system on fish stocks and fishing activities. We recorded more than 300 multispecies fishing trips with 8000 tows on Georges Bank. This study allowed us to apply the DSS to the Northeastern US groundfish fisheries. The DSS incorporates features of a GIS application in processing spatial information. The DSS provides a drawing tool for defining subareas in fishing grounds, such as closed areas, Special Access Programs (SAP) and Essential Fish Habitat (EFH) protection areas. The core component intensively applies simulation modelling, optimization and operations research techniques. The simulation function evaluates the performance of an area management plan based on a predefined set of objectives. The optimization algorithm determines the optimal fishing effort allocation over time and place. Fishing efforts in each subarea and time period are controlled to maximize the value of landings, while bycatch is minimized and other management goals are achieved.

Keywords: decision support system, simulation, optimization, ecosystem, multispecies, spatial management.

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ICES CM 2005/L:07

Implications of marine protected areas on sea scallop recruitment in the Northwest Atlantic

Jacob I. Nogueira and Kevin D.E. Stokesbury

The US portion of the largest sea scallop (*Placopecten magellanicus*) resource in the world is managed using a yield-per-recruit model that assumes no stock recruitment relationship. One may exist but information is conflicting and inconclusive. The scallop stock was severely overfished until 1998, but rebounded and produced the highest recorded harvest in 2003. Extremely high densities of adult scallops in the Georges Bank marine protected areas (MPA) and a new survey technique enable a new examination of recruitment. Using video surveys we evaluated recruitment in distinct areas and examined its association with adult density, depth, substrate, filamentous fauna, and predators. Further, we compared the distribution of juveniles and adults on the scale of kilometers and their association with the biological and physical variables to determine if "nursery areas" exist. In 2003 recruitment was lower in the MPA than in fished areas and sufficient to replace the adult population at an instantaneous natural mortality rate of 0.1, but not at a higher rate. High densities of adults protected by the MPA possibly contributed to the drastic rebound of the scallop stock, but they may also impede recruitment if left unfished.

Keywords: Georges Bank, Sea scallop, *Placopecten magellanicus*, recruitment.

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ICES CM 2005/L:08

Benthic habitat mapping: The habitat template approach

Vlad Kostylev, and Charles G. Hannah

We present a novel approach to benthic habitat mapping of the continental shelf. The goal is high resolution (~1 km) maps of the habitat aimed at seabed managers. This goal cannot be attained by interpolating between limited numbers of benthic grabs and trawls distributed across the shelf. We follow Southwood (1977, 1988) and assume that habitat can be characterized along two axes: 'scope for growth' and 'physical disturbance.' This provides a framework for transforming high resolution maps of the physical environment, such as water temperature, bottom depth and sediment grain size, into a map of habitat characteristics which define life history traits of benthic fauna. The map becomes a hypothesis that must then be tested against observations. Using the Scotian Shelf on the east coast of Canada as an example, we discuss the input layers, present the map, and touch on validation.

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ICES CM 2005/L:09

Developing a UK framework for defining the spatial interactions between human activities in the marine environment

S. I. Rogers, P. D. Eastwood, C. A. Houghton, and C. Mills

The increasing levels of interaction between human activities in marine waters, and the calls for a greater use of protected areas throughout shelf seas to conserve marine biodiversity, has led to a serious consideration of the feasibility of marine spatial planning. Integrated planning tools of this sort ensure that management actions taken within each sector are complementary, and thereby minimise impacts to the ecosystem. However, in order to make practical progress with developing such a planning tool, it is necessary to have comprehensive, spatially resolved data for all important sectors. It is also necessary to manipulate and display the information for the benefit of managers and stakeholders. Such data will need to include the spatial and seasonal extent of the 'footprint' of each activity, and the extent of their interactions with other activities that are not spatially resolved, of which the most important is commercial fishing. The purpose of this paper is to describe work in progress in the UK to prepare a framework for the collation and precise description of these data. It provides a methodology for quantifying the spatial footprint of

complex activities, such as marine aggregate extraction and demersal trawling. For other sectors, such as areas protected for nature conservation purposes, it generates simple statistics showing the extent of seabed covered and the restrictions placed on other human activities Key datasets and research needs to complete the task are highlighted.

Keywords: spatial planning, GIS, ecosystem, human activities, MPA.

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ICES CM 2005/L:10

Incorporating spatial dimension into descriptive fishery models

Jonathan Side, and Paul Jowitt

Ecosystem approaches to ocean and fisheries management often require consideration of closed areas, or no take zones. In some circumstances these may appear imperative for biotope or habitat conservation; but in these and other contexts it is often assumed that the creation of closed areas bring benefits to the fishery. Classical models of fishery systems, both analytic and descriptive, are spatially indeterminate, instead treating “the stock” as implicitly isolated from ecosystem processes and their spatial dimensions.

The work described here results from international studies where closed areas are already in place. Concerns and suggestions expressed by fishers were investigated using a simple spatial extension to the basic descriptive model of Schaefer which provides equilibrium solutions for the incorporation of areas closed to fishing. The resulting model suggests that a number of factors are critical when considering the benefit/costs of closed areas, including the present status of the fishery; growth/reproductive rates and dispersion rates; in addition to the size and shape of the areas closed. Ultimately the model suggests management decisions will be a trade off between fishing efficiency and stock security. The authors suggest ways in which anthropogenic impacts can be examined and coupling with ecosystem models might be attempted. Finally the use of analytical models in a similar context is explored.

Keywords: Ecosystem approaches, fishery models, spatial dimension, closed areas.

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ICES CM 2005/L:11

The source-sink model and the fishing disturbance: a dynamic perspective

Fabio Pranovi

The fishing effort results to be patchy distributed both on regional (fishing effort concentrates in more productive areas) and local (trawled area and the neighbouring un-trawled area) scale. Therefore, at different spatial and temporal scales, fishing activity creates a mosaic of recovery stages that can express different functioning and play different roles, such as source or sink, strongly interacting among them. On the local scale, the recovery dynamics observed in different habitats, after an experimental disturbance (fishing haul), evidenced bi-directional relationships between disturbed and undisturbed area. Each of them can alternatively function as source (donor) or sink (attractor) for different functional groups, in relation to different recovery stages. At the beginning of the process, the undisturbed area acts as source of individuals/species, but passing the time, after the opportunistic populations developed, the role can invert and the disturbed area can be a sort of source of impact for the undisturbed one. From this point of view, species abundance patterns are functions of competitive abilities both on regional and local scale and of the dispersal ability. It results that dispersal characteristics of species plays a potential key role in determining the functioning of environments where patchy distribution is maintained by human activities, such as the benthic communities in fishing grounds. All this, according to the hypothesis that high dispersal tends to homogenize the metacommunity, could help to explain the homogenization of benthic communities recorded in heavy trawled areas, such as the Adriatic Sea.

Keywords: Source-sink, recovery dynamics, fishing disturbance, Adriatic Sea.

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ICES CM 2005/L:12 - Withdrawn

Geological and climatic factors most important in determining fish abundance in the northern Baltic

Laura Uusitalo, Sakari Kuikka, Pirkko Kauppila, Pirkko Söderkultalahti, and Saara Bäck

Large fish yield and environmental variable data sets, spanning 21 years and over 1000 km of northern Baltic Sea coast line, were combined to study the large-scale effects of environmental variables on fish abundances over a geographical scale. The study area is characterized by brackish water of varying salinity, eutrophication state, shore density, and thermal conditions. These environmental gradients offer a “natural experimental setting” that allows studying the respective effects of the environmental variables. 16 commercially exploited fish species were included, 4 of them marine, 7 freshwater, and 5 anadromous species. Eutrophication has been seen as a factor behind the change of the fish community in the area. The present analysis, carried out using Bayesian networks, implies that water quality has only a weak effect on fish abundance, however, whereas shore density, which is closely related to availability of suitable spawning grounds, appears as the single most important environmental variable. The fish stocks’ reactions to the eutrophication level differ under different geographical conditions (practically, in different parts of the coast), however. This implies a need for area-specific management. Since species with different reproduction biology and ecological requirements react conversely to the eutrophic status, there may also be a need for prioritizing between the groups.

Keywords: Baltic Sea, environmental gradients, fish abundance, abiotic factors, biotic factors.

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ICES CM 2005/L:13

How foraging strategy influence spatial pattern in seabirds distribution: The case of northern gannets in the Bay of Biscay

Edwige Bellier, Grégoire Certain, Joël Chadœuf, Vincent Bretagnolle, and Pascal Monestiez

According to local enhancement theory, seabirds use conspecifics and/or heterospecifics as indirect cues to detect food patches. Local enhancement can be understood as a cooperative feeding behaviour. In this study, we focus on seabird’s behaviour during food research. In this case, foraging seabirds are assumed to be regularly spaced, to maximize the range prospected and increase chances to find preys. In contrast, when prey patches are identified, seabird’s aggregation is expected around the patch. Data were collected during 6 aerial surveys in the Bay of Biscay from October 2001 to march 2002. From Point process pattern analysis, a statistical test is developed to check this prediction among spatial distribution of Northern Gannets. Hence, gannets are large surface feeders known to be attracted by their conspecifics. First a statistic is defined to test for aggregation or regularity of gannets distribution inside a foraging flocks. Second, a local Monte-Carlo test is used to test significant regularity or aggregation. This procedure is repeated for all foraging flocks. Finally, we test if regularity or aggregation among all foraging flocks occurs more often than expected by chance alone. This statistic procedure allows defining 3 structures of flocks: regular, aggregative and not structured. These different structures are spatially located in the Bay of Biscay. Our results highlight foraging strategy of gannets and are discussed in the context of future study on interspecific spatial interaction, and on interaction between Northern gannets and Fisheries in the Bay of Biscay.

Keywords: foraging strategy, Northern gannets, Bay of Biscay, spatial pattern, aggregation or regular distribution

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ICES CM 2005/L:14 - Withdrawn

Ecosystem modelling: downscaling from the global to the regional

Rosa Maria Barciela, and John Ragnar Siddorn

The Met Office is running a suite of ocean models from global to the coastal scale. Recently these models have been developed to include ecosystem capabilities. By generating boundary conditions from the global models, effective NRT and operational downscaling of ecoystem behaviour has become possible. This is an improvement on traditional regional ecosystem modelling systems where open boundary conditions are generally either zero flux or at best relaxed to climatology.

The deep ocean capability is based on the Forecasting Ocean Assimilation Model (FOAM) which has been coupled with the Hadley Centre Ocean Carbon Cycle Model (HadOCC). FOAM consists of a series of nested operational ocean models that use data assimilation to produce daily analyses and forecasts of temperature, salinity, ocean currents and mixed layer depth up to five days ahead. HadOCC is a simple Nutrient-Phytoplankton-Zooplankton-Detritus ecosystem model with a variable carbon: chlorophyll ratio. Coastal modelling of the European Continental Shelf uses a physical model developed by the Proudman Oceanographic Laboratory (POLCOMS) at a 6km resolution, and Plymouth Marine Laboratory's European Regional Seas Ecosystem Model (ERSEM). ERSEM, which has a proven pedigree in coastal waters, is a complex ecosystem model including both pelagic and benthic systems and has a number of size and functional group classes for phytoplankton, zooplankton and bacteria, as well as detailed nutrient chemistry.

The impact of the spatial resolution on the FOAM ocean models ability to simulate the lower trophic-level ecosystem is examined, and the related impact on coastal modelling in the MRCS 6 km model are discussed.

Keywords: general circulation model, ecosystem model, deep ocean, shelfseas, plankton, ERSEM, downscaling.

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ICES CM 2005/L:15 – Withdrawn

ICES CM 2005/L:16

Indices for capturing spatial pattern and change across years of a fish population: an application on European Hake (*Merluccius merluccius*) in the Bay of Biscay

Mathieu Woillez, Pierre Petitgas, Jacques Rivoirard, Jean Charles Poulard, and Nicolas Bez

Collapse of important fish stocks have revealed that fish stock assessment based on fishery landings at age suffer from a number of limitations. Probably the most serious limitation is that the indication of population collapse is only perceived very late with such data. The present work aims at looking for indices, based on research survey data only, that could capture the spatial pattern of populations and changes across years. A series of candidate statistical indices has been selected or developed for that purpose. In order to handle diffuse population limits, these indices have been designed so that they do not depend on an arbitrary delineation of the domain. The spatial pattern of fish population is described by a variety of indices characterizing location (center of gravity, inertia and anisotropy, spatial patches), spatial extension (positive area, spreading and equivalent area) and microstructure. Collocation between different ages and years is summarized by a global index of collocation. The indices are estimated on the hake data series of bottom trawl surveys performed by IFREMER from 1987 to 2003 in the Bay of Biscay. Behaviour in the spatial indices is analysed, including interaction between the different indices, their relationship with abundance and age, as well as autocorrelation in the time series. The ability of the indices to capture patterns and provide early warning on incoming changes is discussed.

Keywords: Spatial indices, European Hake, geostatistics, Bay of Biscay.

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ICES CM 2005/L:17

The importance of including spatial dynamics in models of fisheries disturbance

Leonie Robinson, Simon Greenstreet, and Gerjan Piet

It is widely understood that many of the major fishing fleets operating in the North Sea do not exhibit random behaviour in their spatial distribution. At the scale of the North Sea and frequently at the scale of the ICES rectangle, fishing is clumped in its distribution. To further complicate this, fishing may have a clumped, even or random distribution in time. When considering the ecological disturbance of fishing to benthic communities these patterns of distribution may have important consequences. In addition, the benthic populations making up a given community vary in both their vulnerability to fishing disturbance and in their motility. Initial exploration of scenarios suggests that motility of the benthos may have very important and unexpected consequences for population level mortality. We explore the implications of incorporating all of these factors in developing increasingly realistic models of the overall ecological disturbance of fishing to the benthos.

Keywords: fishing effort distribution; benthic communities; ecological disturbance.

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ICES CM 2005/L:18 - Withdrawn

Spatio-temporal modelling of the anchovy spawning in the Bay of Biscay

L. Ibaibarriaga, A. Uriarte, M. Santos, P. Petitgas, and J. Massé

This paper presents a first attempt to combine different sources of information such as egg and adult surveys to model the spawning process of the Bay of Biscay anchovy from a general point of view. On the one hand egg surveys can provide information on the spawning habitat of the species and on the other adult surveys allow understanding the age structure of the adult fish population and their distribution on space during the spawning period.

Firstly, all the data available from the egg and adult surveys conducted since 1989 during the spawning period are compiled and potential factors influencing the spawning habitat and the spatial structure of the adult fish are defined. The effect of these variables is analysed using descriptive techniques such as quotient lines, bi-variate plots and weighted distributions. Special attention is paid on years with surveys conducted at different periods given that they provide contrasting and more complete information.

Egg abundance distribution and adult fish structure by age group are modelled in space using generalised linear models and generalised additive models on the potential explanatory variables and additional geographical covariates.

Finally, considerations about the potential for an operative spatio-temporal modelling of the spawning by age groups are presented and discussed.

Keywords: Anchovy, spawning habitat, spatial structure, generalised linear and additive models.

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ICES CM 2005/L:19

Spatio-temporal distribution of phytoplankton in the Bay of Biscay (1998–2004)

Yolanda Sagarminaga, Victoriano Valencia, and Angel Borja

The temporal and spatial evolution of the phytoplankton in the Bay of Biscay during years 1998–2004 was investigated from daily chlorophyll-a concentration images from SEAWIFS (Sea-viewing Wide Field-of-view Sensor), used as an index for phytoplankton biomass.

This study revealed the spatial and temporal heterogeneity of the chlorophyll-a (chl-a) concentration over the area:

Spatially, four areas were differentiated on the basis of their average chl-a records: these areas are generally spatially related to the bathymetry and include the so-called “inner shelf” class, directly influenced by coastal processes, the “middle shelf”, the “shelf edge” and the “offshore” classes.

Temporally, different periods were also identified on the basis of the chlorophyll concentrations values, but also on the oceano-meteorological factors affecting the phytoplancton dynamics: i.e., factors such as solar irradiance and turbulence were very much correlated to the phytoplankton dynamics all over the area for one limited period at the beginning of the year, whereas in successive periods, different areas diverged in their dynamics, and other factors seemed to explain the processes involved in phytoplankton increases or decreases.

The results of these analyses have come up with a spatio-temporal classification of the VIII ICES Subdivision into units defined by their differentiated phytoplankton dynamics.

Keywords: phytoplankton populations dynamics, bay of Biscay, spatio-temporal distributions, SEAWIFS.

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ICES CM 2005 /L:20 – Poster

Spatial distribution of seven species captured by bottom trawling in Algarve (Portuguese southern coast): using multivariate geostatistical methods

Beatriz Mendes

This poster illustrates spatial distribution in abundance and individual mean size of seven species (four crustacean species: *Parapenaeus longirostris*, *Aristeus antennatus*, *Aristaeomorfa foliacea*, *Nephrops norvegicus*, and three fish species: *Merluccius merluccius*, *Trachurus trachurus* and *Micromesistus poutassou*) evaluated by geostatistical models. A total of 126 stations carried out off the Portuguese southern coast (Algarve), between March and May 1993, along a bathymetric gradient ranging from 152 to 662 m.

Relative semi-variograms were fitted to a spherical model for all species. Abundance maps obtained by punctual kriging showed a species-specific spatial segregation in high-density areas, with a differential bathymetric distribution for these species. The analysis of the multivariate spatial models was useful to display the spatial structure of species in terms of species responses to external parameters such as lunar periodicity.

Keywords: Crustacean; multivariate geostatistical models; kriging; Algarve.

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ICES CM 2005/L:21

Using geostatistics to quantify annual distribution and aggregation patterns of fishes in the Eastern English Channel

S. Vaz, C. S. Martin, B. Ernande, F. Coppin, S. Harrop, and A. Carpentier

The eastern English Channel is an area with strong hydrodynamic features supporting, among other human activities, an important fishery exploitation. Since 1988, IFREMER (French Research Institute for Exploitation of the Sea) has been carrying out an essential ground fish survey primarily dedicated to ICES annual assessment of major commercial fish stocks in this area. However, these fisheries independent data also offer the opportunity to study of the distribution patterns of observed fish species using geostatistical techniques. Geostatistics embody a suite of methods for analysing spatial data and allow the estimation of the values of a variable of interest at non sampled locations from more or less sparse sample data points. Geostatistical estimation (kriging) is different from other interpolation methods because it uses a model describing the spatial structure and variation in the data – the variogram. The latter is the central tool of geostatistics and is essential for all of the other geostatistical methods. Kriging was used to produce distribution maps of

several fish species over 17 years (1988–2004) and variogram parameters reflected changes in distribution patterns over time. Fish aggregation patterns and inter-annual variability were examined in the light of geostatistical analyses of fish distribution and a few example of this study will be presented.

Keywords: eastern English Channel, CHARM, fish spatial distribution patterns, geostatistics

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ICES CM 2005/L:22

Upscaling unique ecosystem-climate relationships for the Bering Sea

James E. Overland, and N. A. Bond

While large-scale indices (NAO, PDO, etc.) represent robust measures of climate variability and have been used with downscaling of temperature and precipitation, we illustrate the advantage of an upscaling approach for ecosystem applications. The benefit is starting with important local environmental factors which do not necessarily relate to the most prominent source of large-scale atmospheric variability. In winter for the Bering Sea, many biological processes are associated with sea ice, which in turn is associated with the strength of northerly winds and sensible and latent heat fluxes. This wind component does not map onto the Pacific Decadal Oscillation-PDO, but does map onto the strength of the Siberian High. In contrast, transport of nutrients responds to the curl of the wind stress, which does relate to the PDO. In summer the primary mechanisms are net surface heat flux and wind mixing; the former is linked to North Pacific-NP mode and accounts for a long term warming trend, but the latter is due to local forcing. Major ecological responses, such as the cocclithophorid bloom of 1997 and variations in pollock, are controlled by intra-seasonal events. Strong pollock recruitment in 1978 1982, and 1996 required both warm temperatures at the end of winter and enhanced wind mixing in early summer. While the warmer temperatures after 1976 associated with the PDO regime shift was a necessary condition, strong recruitment did not occur until both factors were present. Understanding biophysical mechanisms combined with upscaling, is a valid approach for developing unique ecosystem-climate relationships.

Keywords: climate, indices, PDO, pollock, recruitment, Bering Sea.

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ICES CM 2005/L:23

Investigating the interaction between population spatial organisation and population dynamics using an age-structured multi-site matrix model on anchovy in Biscay

Pierre Petitgas, and Sandrine Vaz

The spatial organisation of a population is expected to play a central role in the context of population collapse and recovery. Habitat occupation and its biological traits are expected to be related to population viability at low population numbers. These working hypotheses were investigated on Bay of Biscay anchovy, a population potentially collapsing every year since both fishery and population depend on recruitment success. The population has been monitored since 1987 by spring acoustic surveys which provided data on population demography (numbers at age), fish biological traits (length, weight) and their spatial patterns. Based on numbers at age and biological traits, five distinct zones were identified. Multi-site Leslie-type matrix models were fitted to model the transitions between population configurations from one year to the next. The average matrix reflected the long-term dynamics of the population. The elasticity analysis of this matrix showed high relation between fertility on a particular zone and population growth (recruitment), making this zone an essential spawning habitat to the population renewal and maintenance. The inter-annual variation in the population spatial pattern and dynamics was modelled by a time series of matrix types. Matrix types were obtained by classifying the transition matrices using their eigen-values. Differences between the matrix types were related to changes in the spatial distribution of fertility, meaning that population dynamics was related to population spatial organisation.

Keywords: matrix population model, population spatial structure, recruitment, time series.

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ICES CM 2005/ L:24

Distribution and feeding of herring (*Clupea harengus*) in the Norwegian Sea during spring, as determined from generalised additive models

Esben Moland Olsen, W. Melle, S. Kaartvedt, J. C. Holst, and K. A. Mork

The Norwegian spring-spawning herring is the world's largest herring stock. The stock collapsed to the state of commercial extinction in the late 1960s, but is now considered to be fully recovered. During spring and summer, the Norwegian spring-spawning herring feed heavily on zooplankton in the open waters of the Norwegian Sea, building energy reserves for future overwintering and spawning in Norwegian coastal waters. Historically, there has been much variability in the spatial extent of the herring feeding migration. Here, we analyse the variability in herring distribution and feeding in the period from 1996 to 2004, using survey data on hydrography, zooplankton and herring collected throughout the Norwegian Sea in May each year by the Norwegian Institute of Marine Research. The spatial component is handled by fitting generalised additive models (GAMs) to the survey data. GAMs are an extension of generalised linear models, allowing flexible nonparametric effects of covariates (such as latitude and longitude). We describe the spatial and temporal variability in ambient temperature, salinity and zooplankton biomass, and elucidate how these are linked to the distribution and feeding of the herring.

Keywords: Feeding migration, generalised additive models, herring, Norwegian Sea, zooplankton.

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ICES CM 2005/L:25

Associations between bathymetric, geologic and oceanographic features and the distribution of the British Columbia groundfish trawl fishery

A. Sinclair, K. Conway, and W. Crawford

We have assembled current information on the groundfish trawl fishery off British Columbia, Canada, the surficial geology of the fishing grounds, and the prevailing physical oceanography of the area. This was used to describe conditions that are important for determining fishing locations and high levels of fish density. Detailed tow-by-tow data were used to map the spatial distribution of fishing effort, total fish density, and the densities of the species making up 95% of the total catch. Previously published maps of the surficial geology, which consist of exposed bedrock, glacial tills, sands, gravels and muds, have been digitized in a GIS format for analysis. Oceanographic studies have revealed the main circulation features of the continental shelf of British Columbia. These include fronts at the shelf break, circulation around the main banks, eddies, and internal tides. Maps of fishing and geologic data were overlaid to reveal an affinity of fishing to areas covered by sands and gavels and an aversion to areas dominated by exposed bedrock and thin sediments over bedrock. Species-specific affinities to different sediment types were also demonstrated. Areas of high fish density occurred along frontal zones, the steep sides of banks, and across one of the three main troughs. These are areas where currents are relatively high and likely to concentrate zooplankton. In general, geologic features were more strongly associated with the location of fishing and the spatial distributions of individual species. Physical oceanographic conditions were more strongly associated with the distribution of total fish density.

Keywords: Fish distribution, fishery distribution, surficial geology, physical oceanography.

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ICES CM 2005/L:26

From Kelvin waves to fishers' trajectories: evidences of multi-scales teleconnections in the Peruvian upwelling ecosystem

Sophie Bertrand, Erich Diaz, Boris Dewitte, Gordon Swartzman, Arnaud Bertrand, and Mariano Gutiérrez

Eastern boundary upwelling ecosystems are extremely dynamic over a wide range of spatiotemporal scales. This is particularly the case for the Humboldt Current ecosystem, which is characterized by short term, seasonal, inter- annual (Niño/Niña events) and inter-decadal regimes of variability. In such a context, we aimed to study how equatorial physical forcing may affect coastal water mass distribution, fish distribution and fishers spatial behaviour. For that purpose, we used data from scientific surveys conducted in Peru between 1983 and 2003 to characterize water masses, fish abundance and spatial distribution. Fishers' spatial behaviour was characterized from satellite vessel monitoring system data from 1999 to 2003. From a statistical exploration and wavelet analysis performed on a set of indicators, there was evidence that (1) fish spatial distribution is well explained by water-mass spatial dynamics supporting habitat based determination of fish distribution; (2) fishers' efficiency is constrained by the way fish biomass "fills" the space, and in different ways according to the spatial scale; (3) fishers' spatial behaviour responds to fish spatial distribution across scales (4) energy peaks for the studied indicators presented the same intra-seasonal and inter-annual characteristic scales as the equatorial Kelvin waves. We conclude that fish biomasses and spatial distributions as well as spatial behaviour of fishers were modulated by coastal physical activity forced at distance by the Kelvin equatorial waves.

Keywords: multiscale analysis, spatiotemporal variability, fish and fishers spatial behaviour, Kelvin equatorial waves, water masses, wavelet analysis, Peruvian upwelling ecosystem.

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ICES CM 2005/L:27 – Poster

The Baltic Sea as habitat

Evald Ojaveer, and Margers Kalejs

The two-layer brackish Baltic Proper is separated from the seas of oceanic salinity by the salinity barrier (the Transition Area) and from the single-layer large gulfs by the temperature/freshwater barrier (the NW region of the Baltic Proper). The Baltic Sea consists of three large natural units – the Transition Area, Baltic Proper and the large gulfs (Gulf of Bothnia, Gulf of Finland and Gulf of Riga). Major regions with conventionally homogenous nature of environmental conditions (dynamics of water masses, salinity, thermal conditions, and concentration of oxygen/hydrogen sulphide) can be differentiated in these units. The zones of elevated biological productivity present in every region, have stimulated adaptation of organisms to the conditions in the region, i.e., – have contributed to the formation of ecological subsystems. The Transition Area offers possibilities for stepwise adaptation of marine organisms to the conditions in the Baltic. The SW region is the most stable subsystem in the Baltic Proper. The near- bottom layers of the Eastern and NW regions are periodically not habitable by higher life forms. The Gulf of Bothnia, of Finland and of Riga are populated by the marine organisms adapted for reproduction throughout the Baltic Sea, glacial relicts and freshwater species.

Keywords: Baltic Sea, natural regions, barriers, productivity zones.

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ICES CM 2005/L:28 – Poster

Definition of fishing trip types in the bottom trawl fisheries off the Portuguese coast

Aida Campos, Paulo Fonseca, Tereza Fonseca, and Joaquim Parente

The bottom trawl fishery in Portuguese continental waters is a multi-species fishery where a high number of commercial species (fish, crustaceans and cephalopods) are landed by a fleet composed of more than 100 trawlers. This paper presents the results obtained from applying classification methods to the 2002 and 2003 monthly landings per vessel with the purpose of defining fishing trip types (FTTs). A number of different FTTs emerged from the analysis, each defined by the relative importance of their target and by-catch species. A correspondence between some of these FTTs and fleet components could be established, indicating the existence of groups of trawlers developing the same fishing pattern over time.

Generalised linear models (GLMs) were employed to analyse the relationships between variables such as year, month and vessel characteristics with landing rates for the most important species in these groups.

The outcome of the analysis allows for a better understanding of the fleet dynamics in a fishery where a high number of vessels operate over different fish assemblages. A more precise definition of fleet segments will contribute to simplify the complex task of critically examining discards, fishing effort or alterations to fishing gear in order to improve fisheries management.

Keywords: Bottom trawl fisheries; Fishing trip types; Generalised linear models; Portuguese coast.

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ICES CM 2005/L:29 – Poster

The changes of marine algae flora and phytocenosises of Barents Sea (Russian coast) as the indicator of climatic fluctuations of North Atlantic region

Vadim A.Shtrik

The three year studies of coastal ecosystem by the program of Coastal Ecosystem Monitoring of Kola peninsula of VNIRO provided new results on composition and structure of near-shore communities of Kola Peninsula (Barents Sea). The monitoring study based on biocenosis stratification of coastal area by method of diving transects and detailed description of quantitative and qualitative indicators of ecosystem. The phyto-geographical subdivision of coastal line was made based on dominant and floristic indexes of biodiversity and structure of phytocenosises.

The results obtained indicate that there were appear at least 11 new species of *Chlorophyta, Phaeophyta, Rhodophyta* algae at the offshore ecosystem of Barents Sea, Kola Peninsula during the lust decades. Some of them were found for the first time at Barents Sea, while the others were discovered for the first time for Seas of Eurasian part of Arctic Ocean. However, these new locations were the results of expansion of species and enlargements of natural habitats. The same patterns of natural habitats extension for all those algae probably are arising from the effect of the global climatic changes at the region of North Atlantic.

The paper shows the models of spatial extension of natural habitats for discovered sea algae. An attempt was made to collate long-term fluctuations of climate in offshore zone of Barents Sea with the tendency of spatial expansion of sea algae and the changes of phytocenosis composition of local offshore ecosystems. The new method of long term monitoring based on index of floristic biodiversity and phyto-geographic analyses of local areas of the coast was work out and applied.

Keywords: offshore ecosystem, algae, Barents sea, new species, macrophytes, phytocenosis, North Atlantic, climate fluctuations.

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ICES CM 2005/L:30 – Poster

Using UWTV surveys to test conceptual ecosystem models of *Nephrops* population distributions

Colm Lordan, Glen Nolan, Fiona FitzPatrick, and Richard Briggs

Nephrops live on the seabed where the benthic habitat is suitable for them to construct unlined burrows. Despite the economic importance of *Nephrops* fisheries the assessments and management of many stocks is problematic. Underwater television (UWTV) surveys originally designed and carried out as stock assessment tools provide detailed information on underlying distribution of *Nephrops* populations. In this paper we examine conceptual models of the ecosystem on the Aran grounds and in the Western Irish Sea where two important *Nephrops* stocks are exploited. Geo-referenced data on depth, sediment, oceanographic process and on the distribution of the fishery are examined as explanatory variables to describe the spatial distribution of *Nephrops* observed in UWTV surveys. The findings are discussed in terms of future management of the fisheries within the ecosystem and future survey design.

Keywords: *Nephrops*, UWTV, assessment, ecosystem.

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ICES CM 2005/L:31 – Poster

Impact of sea star predation on sea scallops in marine protected areas on Georges Bank

Michael C. Marino II, and Kevin D. E. Stokesbury

Georges Bank supports the world's largest natural sea scallop (*Placopecten magellanicus*) resource. Since the establishment of three Marine Protected Areas (MPAs) in 1994, the biomass of scallops has increased, with 80% of the resource presently in these areas. High scallop abundance may attract high densities of predators, such as sea stars (*Asterias* spp.) in these MPAs, leading to higher natural mortality. Presently, a single estimate of instantaneous natural mortality (M = 0.1) is used in the management of the Georges Bank scallop fishery. Using underwater video surveys we estimated spatially specific sea star density and scallop natural mortality on Georges Bank. Sea star mean densities were higher in the MPAs than in open areas. Intense predation events were observed and scallop natural mortality was higher in specific MPAs. For example, in 2003, the observed scallop biomass was 18 656 mt tons lower than projected in the southern portion of Closed Area II, suggesting natural mortality was greater than M = 0.1. High densities of large sea stars and dead scallops observed in this MPA indicate predation may be responsible for the scallop mortality. This suggests predator – prey interactions should be considered when using MPAs to protect marine resources.

Keywords: Georges Bank, Sea scallop, *Placopecten magellanicus*, Sea star, *Asterias* spp., Predation.

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ICES CM 2005/ L:32 – Withdrawn

ICES CM 2005/L:33 – Poster - Withdrawn

Feeding of Atlantic salmon (*Salmo salar* L.) postsmolts in the Northeast Atlantic

Monika Haugland, Jens Christian Holst, Marianne Holm and Lars Petter Hansen

The postsmolt stage of Atlantic salmon is of particular interest as the major marine mortality of salmon at sea occurs during this period. Nonetheless few investigations have been made on their diet in the oceanic areas of the Northeast Atlantic. In the present study postsmolts were sampled in 1991 and 1995–2003 from early June to mid August during northward migration and on the feeding areas (55º–75ºN and 10ºW-20ºE). The main focus was on the Atlantic waters of the Norwegian Sea. In the Slope Current west of the British Isles in early summer the postsmolts fed on 0-group of blue whiting and sandeel which together with other fish constituted 80–90% of the prey by weight. One of two postsmolts had also fed on crustaceans in this area. 0-group of sandeel was the main prey in the northern part of the North Sea at this time of the year. In the Norwegian Sea fish constituted two-thirds of the prey by weight with 0-group herring as the most important species. Other fish found in the stomachs were sandeel, gadoids, pearlside, lanternfish and redfish, most of them 0-group. Crustaceans constituted about one-third of the total prey by weight and amphipods of the species *Themisto abyssorum* (TL 2–8 mm) dominated this group. Copepods and young stages of krill were recorded in very

limited amounts by weight. Annual differences in diet were observed, probably reflecting both variations in abundance of the prey species and a patchy distribution of prey and catches of postsmolt.

Keywords: Atlantic salmon, wild salmon, diet, feeding preference, Northeast Atlantic, ecology.

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ICES CM 2005/L:34 – Withdrawn

ICES CM 2005/ L:35 – Poster

Biodiversity-ecosystem processes in heterogeneous environments

P. L. Luque, G. Hernandez Milian, M.Bulling, Kirstie Dyson, E.N. Ieno, G.J. Pierce, M. Solan, D. Raffaelli, and D. Paterson

Biodiversity loss within a trophic level might affect potentially species at others levels, directly through changes in competitive and consumer-resource interactions, or indirectly by changes in ecosystem processes. Ecosystem processes may be substantially affected by heterogeneity and an interpretation of the relationship between heterogeneity and ecosystem processes is important for management of disturbance in marine benthic systems.

We use a replicated mesocosm approach to manipulate species richness (biodiversity) in a multi-patch environment containing four macro-benthic species with contrasting mobilities, modes of bioturbation and effects on ecosystem processes (the polychaete, *Hediste diversicolor*; the mud shrimp *Corophium volutator*; the bivalve *Macoma balthica*; and the gastropod *Hydrobia ulvae*). Patches of variable habitat quality are established by enriching the sediment with powdered algae (*Enteromorpha* sp.). The addition of Enteromorpha significantly enriches the food quality of the sediment, but is not sufficient to generate a hostile physico-chemical environment. We measure NH4-N, NOx-N and PO4-P release, along with primary production (using non-invasive PAM fluorometry) and the net rates of inter-patch movements for all three species across a range of density levels. System behaviour is modelled in terms of locally coupled equations describing dynamic change within the cells within the model, which are occupied by connected populations.

Keywords: Biodiversity loss, ecosystem process, macro-benthic species.

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ICES CM 2005/ L:36 – Poster - Withdrawan

Spatial onset of anchovy recruitment in the Bay of Biscay: JUVENA surveys

Guillermo Boyra, Paula Alvarez, Unai Cotano, and Andres Uriarte

The spatial onset of the recruitment of anchovy in the Bay of Biscay is being studied under the frame of the project JUVENA. The surveys aim to estimate annually the spatial distribution and relative abundance of juvenile anchovies and their growth condition at the end of the summer in a sampled portion of the Bay of Biscay bounded at 5º W and 46º N. The long term objective of the project is to assess the recruitment to the fishery the following year. The surveys include acoustic mapping of fish dispersion and abundance; purse seine hauls for biological sampling and species identification; and continuous sea-surface temperature and salinity measurements plus CTD casts for characterization of the physical oceanographic habitat. Results are presented from the first two annual surveys in 2003 and 2004, in the context of other acoustics surveys on juvenile anchovy in the Bay of Biscay and in comparison with the adult (age 1) abundance the following years. Some difficulties to achieving of the program objectives that were detected during the first two JUVENA surveys are discussed, along with the possibilities of expanding the selected boundaries for the coverage area, because of doubts on the role of the Northern parts of the Bay of Biscay on the onset of the overall anchovy recruitment.

Keywords: anchovy juveniles, nurseries, recruitment.

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ICES CM 2005/L:37 – Poster

Hake (*Merluccius merluccius* L.) spatial and temporal recruitment variability as a key species in the Portuguese upwelling ecosystem

Fátima Cardador, Maria de Fátima Borges, Corina Chaves and Steve Groom

The southern stock of European hake (*Merluccius merluccius* L) has been declining for the past 20 years. In 2004 an unexpected bloom of juvenile hake was produced by a very low spawning stock biomass.

Global environmental effects (as represented by the North Atlantic Oscillation) on the Hake recruitment time-series are investigated and linked with the spatial dynamics of plausible processes.

Keywords: European Hake, Portugal, recruitment variability, environment, NAO, spatial dynamics.

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ICES CM 2005 /L:38 – Poster

Predator-prey interactions in a changing habitat: examples from Baltic littoral planktivores

Eveliina Lindén, Maiju Lehtiniemi, Sini Heino, and Markku Viitasalo

The shallow coastal areas of the Baltic Sea are characterized by aquatic macrophyte vegetation, which provides a potential predation refuge. Thereby it modifies the predator-prey interactions of animals dwelling in the littoral zone, such as three-spined sticklebacks (*Gasterosteus aculeatus*), perch (*Perca fluviatilis*), mysid shrimps (*Neomysis integer* and *Praunus flexuosus*), and prawn (*Palaemon adspersus*). We have studied these interactions with manipulative laboratory experiments. Stickleback larvae and mysids respond to the presence of their predators (perch and prawn) behaviourally, adjusting their swimming and feeding activities and increasing the use of macrophyte refuges. However, there are significant differences between macrophyte species, both structurally and chemically. Some offer a preferred predation refuge, like the macroalgal species, bladder wrack (*Fucus vesiculosus*) and stonewort (*Chara tomentosa*), and some are avoided, like perfoliate pondweed (*Potamogeton perfoliatus*), or even lethal, like Eurasian watermilfoil (*Myriophyllum spicatum*). Also the predators' usage of the vegetation differs between species, perch being more active and spending less time in vegetation than prawn. The species composition of the macrophyte community is constantly changing due to coastal land uplift and anthropogenic influence. Some macrophyte species (pondweed and milfoil) benefit from disturbances like nutrient loading, boating, and dredging, while some (macroalgae) are declining rapidly. The ability of the stickleback larvae and littoral mysids to adapt their behaviour to increase their survival in different habitats and predation regimes is discussed, and the possible consequences of coastal habitat changes to these important prey populations are highlighted.

Keywords: anti-predator behaviour, fish larvae, mysids, macrophytes

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ICES CM 2005/L:39 – Poster

Mapping benthic substrate along the northwest Atlantic Ocean continental shelf with underwater video surveys

Bradley P. Harris, and Kevin D. E. Stokesbury

Substrate is fundamental to the designation of Marine Protected Areas (MPA), Habitat Area of Particular Concern (HAPC), and Essential Fish Habitat (EFH). For example, substrates identified as containing “gravel” influenced the creation of three MPAs encompassing 20 000 sq. km of sea floor on Georges Bank in 1994, and a HAPC on the Northern Edge of Georges Bank in 1998, while determining EFH for many New England marine species relies heavily on substrate distributions. Unfortunately, substrate data for the Mid-Atlantic and Georges Bank regions are spatially and temporally patchy, have low sampling frequencies, and dissimilar sampling methods. We employed a centric, systematic underwater video survey of benthic substrates including sand, granule/pebble, cobble, boulder, and macroinvertebrates. We mapped the distribution of benthic substrates using 35 000 georeferenced video samples covering 60 000 sq. km of sea floor in waters 20 to 200 meters deep. The Mid-Atlantic was predominantly sand, Georges Bank MPA were predominately sand with small granule/pebble regions, the western Great South Channel was predominately granule/pebble with distinct cobble and boulder features, and the Northern Edge HAPC was predominately granule/pebble. This research provides essential data for MPA, HAPC, and EFH definitions on a sampling scale two orders of magnitude higher than previous data.

Keywords: Georges Bank, Sea scallop, *Placopecten magellanicus*, shell growth.

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